ACTIVE MUSCLE ASSISTANCE DEVICE AND METHOD

REFERENCE TO EARLIER APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Serial No. 60/485,882, filed Jul. 8, 2003, which is entitled "ELECTROSTATIC ACTUATOR WITH FAULT TOLERANT ELECTROSTATIC STRUCTURE" and U.S. Provisional Patent Application Serial No. 60/429,289, filed Nov. 25, 2002, which is entitled "ACTIVE MUSCLE ASSISTANCE DEVICE."

BACKGROUND

[0002] There is a strong need for devices to assist individuals with impaired mobility due to injury or illness. Current devices include passive and active assistance and support devices, mobility devices and strength training devices.

[0003] Strength training devices, such as weights and exercise equipment, provide no assistance in mobility. Nor do such devices provide joint support or muscle support or augmentation.

[0004] Passive assistance devices, such as canes, crutches, walkers and manual wheelchairs, provide assistance with mobility. However, individuals using such devices must supply all of the power needed by exerting forces with other muscles to compensate for the one that is weak or injured. Additionally, passive assistance devices provide limited mobility.

[0005] Alternatively, passive support devices (passive orthoses), such as ankle, knee, elbow, cervical spine (neck), thoracic spine (upper back), lumbar spine (lower back), hip or other support braces, provide passive joint support (typically support against gravity) and in some cases greater mobility. Similarly, however, using such devices requires individuals to exert force with a weak muscle for moving the supported joint. Moreover, manual clutch-based braces require the user to activate a brace lock mechanism in order to maintain a joint flexion or extension position. This limits the user to modes of operation in which the position is fixed, or in which the device provides no support or assistance.

[0006] By comparison, powered assistive devices, such as foot-ankle-knee-hip orthosis or long-leg braces, provide assistance in movement and support against gravity. A powered foot-ankle-knee-hip orthosis is used to assist individuals with muscular dystrophy or other progressive loss of muscle function. The powered foot-ankle-knee-hip orthosis is also used for locomotive training of individuals with spinal cord injuries. However, this type of powered foot-ankle-knee-hip orthosis typically uses a pneumatic or motorized actuator that is non-portable. Another type of device, the electronically controlled long-leg brace, provides no added force to the user and employs an electronically-controlled clutch that locks during the weight bearing walk phase. This limits the mobility of the user when walking in that the user's leg remains locked in extended position (without flexing).

[0007] A mobility assistance device such as the C-Leg®, is a microprocessor-controlled knee-shin prosthetic system with settings to fit the individual's gait pattern and for walking on level and uneven terrain and down stairs. (See, e.g., the Otto Bock Health Care's 3C100 C-Leg® System). Obviously, since this rather costly system is fitted as a lower limb prostheses for amputees it is not useful for others who simply need a muscle support or augmentation device.

[0008] A number of power assist systems have been proposed for providing weight bearing gait support. One example known as the lower limb muscle enhancer is configured as a pneumatically actuated exoskeleton system that attaches to the foot and hip. This muscle enhancer uses two pneumatic actuators, one for each leg. It converts the up and down motion of a human's center of gravity into potential energy which is stored as pneumatic pressure. The potential (pneumatic) energy is used to supplement the human muscle while standing up or sitting down, walking or climbing stairs. Control of the system is provided with pneumatic sensors implanted into the shoes. Each shoe is also fitted with fastener that receives one end of the rod side of a pneumatic actuator, the other end of the rod extending into the cylinder side of the actuator. Although the cylinder is provided with a ball swivel attachment to the hip shell, the hip, leg and foot movements are somewhat limited by the actuator's vertically-aligned compression and extension. The pneumatic actuator helps support some of the body weight by transmitting the body weight to the floor partially bypassing the legs. All control components, power supply, and sensors are mounted on a backpack. Thus, among other limitations, it is relatively uncomfortable and burdensome.

[0009] Another powered assistive device is a hybrid assistive leg that provides self-walking aid for persons with gait disorders. The hybrid assistive leg includes an exoskeletal frame, an actuator, a controller and a sensor. The exoskeletal frame attaches to the outside of a lower limb and transmits to the lower limb the assist force which is generated by the actuator. The actuator has a DC-motor, and a large reduction gear ratio, to generate the torque of the joint. The sensor system is used for estimating the assist force and includes a rotary encoder, myoelectric sensors, and force sensors. The encoder measures the joint angle, the force sensors, installed in the shoe sole, measure the foot reaction force, and the myoelectric sensor, attached to the lower limb skin surface, measures the muscle activity. Much like the aforementioned muscle enhancer, the controller, driver circuits, power supply and measuring module are packed in a back pack. This system is thus as cumbersome as the former, and both are not really suitable for use by elderly and infirm persons.

[0010] Active mobility devices, such as motorized wheelchairs, provide their own (battery) power, but have many drawbacks in terms of maneuverability, use on rough terrain or stairs, difficulty of transportation, and negative influence on the self-image of the patient.

[0011] Currently there is a need to fill the gap between passive support devices and motorized wheelchairs. Furthermore, there is a need to remedy the deficiencies of muscle or joint support and strength training devices as outlined above. The present invention addresses these and related issues.

SUMMARY OF THE INVENTION

[0012] In accordance with the aforementioned purpose, the present invention helps fill the gap between passive support devices and motorized wheelchairs by providing an active device. In a representative implementation, the active